THE PULSAR MAGNETIC WINDOW

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Abstract: *Triggering of the spark discharges in the Ruderman and Sutherland model by background gamma rays is shown to be effective only within a narrow range of neutron star magnetic fields centred on 2.5×10^{12} gauss. This calculated range of field strengths is in good agreement with 'observed' values, suggesting that (a) such triggering is operative, and (b) that neutron stars with much stronger fields do not function as pulsars.*

In the RS model (Ruderman and Sutherland, 1975) after every gap discharge, fresh charges must be introduced in the polar gap to restart the sparking. We report here briefly on the consequence of the hypothesis that such reignition is effected by the diffuse gamma ray background only which must always be present. A detailed treatment and further references may be found in Shukre and Radhakrishnan (1980).

The diffuse background gamma rays with energies $\gtrsim$ 1 MeV can supply charged particles to the gap on the 10-10^2 μs timescale, if firstly they manage to reach the gap, and secondly they produce electron-positron pairs within it. Thus if τ_1 and τ_2 are the optical depths for these stages respectively, the efficiency of this conversion from gamma rays to pairs is

$$\eta = e^{-\tau_1} (1-e^{-\tau_2}).$$

Although other processes may contribute to the optical depths, we attribute them solely to electron-positron pair creation by photons in the neutron star magnetic field. Using the mean free path for this process, and taking the stellar magnetic field to be dipolar, the number N of pairs produced per second in the gap can be numerically evaluated as a function of B_{12}, the stellar magnetic field at the pole and R_6 the stellar radius (in units of 10^{12} gauss and 10^6 cm respectively). It is found that when B_{12} is large, almost no photons reach the gap, and N is very small. On the other hand when B_{12} is small, a large flux reaches the gap but goes through it without producing pairs, and N is small again; this is due to the steepness of the diffuse gamma ray spectrum at high energies.

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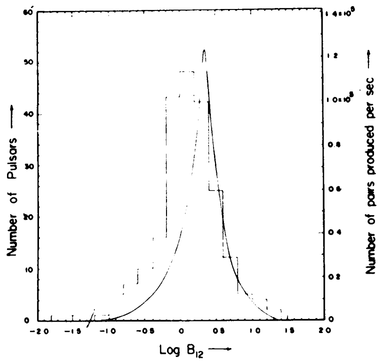

Fig. 1. The number of pairs produced per second within the gap by the diffuse gamma rays as a function of the pulsar magnetic field and the histogram of the number of pulsars with derived fields lying in equal logarithmic intervals.

The curve in Fig. 1 shows N as a function of B_{12} for $R_6=1$. The shape of the curve and the position of the peak are insensitive to the value of R_6 or the dependence on radius assumed for the gap size. The triggering of discharges is seen to be effective only in a narrow range of B_{12}. As the pulsar activity must cease in the absence of sparking, the pulsar magnetic fields B_d derived from observations should also show a narrow distribution peaked around 2.5 x 10^{12} gauss if our hypothesis is correct. To compare the two, we have included the B_d distribution in Fig. 1, in which the histogram shows the number of pulsars with derived magnetic fields lying in equal logarithmic intervals.

The magnetic fields were derived with the usual assumption of magnetic dipole braking and with $R_6=1$. The dependence of the derived field on the assumed moment of inertia is very weak, as is the dependence of the moment of inertia on mass in most neutron star models. We have therefore assumed a standard value of $I=10^{45}$gm cm^2. The pulsar periods and slow-down rates were obtained from Newton et al. (1980) and a number of references therein which are also given below. We interpret the agreement seen in Fig. 1 between the curve and the histogram to mean that the probability of pulsar activity is high for those neutron stars whose magnetic fields lie in the window defined by the curve.

Although there is very good agreement on the high field side. the B_d distribution is seen to be broader than the window and extends further on the low field side. Possible reasons are a spread in the radii of the neutron stars, and/or a deviation from exact dipole radiation braking. However, we consider the most likely reason to be the presence of multipole components in the stellar magnetic field. They will extend the window curve (which so far has included only the dipole component) on the low field side, thus considerably improving its agreement with the histogram.

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DISCUSSION

F.G. SMITH: The apparently low fields of the pulsars on the left of the histogram might be a result of small angles between spin and magnetic axis, giving too low a value calculated from P and $\dot{P}$.

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